A review on historical distribution, nutritional profile and economic importance of black soldier fly larvae

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Abstract

Hermetia illucens is a member of Hermetiinae subfamily of Stratiomyidae family. It is native to America where BSF may currently be found from Argentina to Canada. Adult flies lack stingers mouthparts and digestive organs therefore they do not bite and consume food. The female flies have reddish-brown abdomen whilst the male is 20–25 mm long with bronze belly. The BSF larvae body composition varies between 7 and 39% dry matter with fat making up largest portion. The purpose of this review is to understand the economic importance of Black soldier fly. Among substrates protein content ranges from 37-63% dry matter. The food that BSF larvae eat determines their body composition even though they often have high protein and fat values. High concentrations of lauric, palmatic and oleic acid were observed in larvae and prepupae of *Hermetia illucens*. They have been demonstrated to contain 19–40% monosaturated and polyunsaturated fatty acids and 58-72% saturated fatty acids. Calcium, iron, zinc, copper, manganese, phosphorus and zinc are all highly concentrated. The larvae are an innovative waste management source that treat biowaste. Through this process garbage is transformed into the waste of larval biomass. The dry mass is decreased and basic components produced for the manufacture of fertilizer and soil conditioner lubricants conditioner for soil bio diesel medicines and animal feeds. To conclude, the BSFL biowaste processing can provide

high value marketable products that support sustainable and profitable development resource recovery based approaches to waste management.

Key words: Black soldier fly, *Hermetia illucens*, Frass, Biodiesel, Waste management, Fertilizer production

1. Introduction and Historic distribution:

Black soldier fly (*Hermetia illucens*) is a member of Stratiomyidae family. Three of five genera that are known to exist in subfamily (Hermetiinae) are exclusive to the Neotropical Region. while one is found in Australia. There are examples of the surviving genus *Hermetia Latreille* 1804 throughout the proximity (12) tropical (52) Afrotropical group (3) The regions of Australasia (10) and the Orient (14)making it by far the most speciose (1).

An essential foundation for understanding organism distributions is historical records. The BSF is the world most commonly distributed stratiomyid. It is regarded as cosmopolitan in tropical subtropical and temperate climates. It is native to the America where BSF may currently be found from Argentina to Canada (2). The first confirmed Palearctic historical record of *H. illucens* is from 1926 and comes from Malta in southern Europe. It is possible that the species was brought to Europe some 500 years ago (Lindner 1936). In 1950 and 1960 this easily identifiable species began to expand throughout Europe primarily along the Spanish French and Italian Mediterranean coasts (3). The species has been observed moving northward in Central Europe in more recent times records from Germany and the Czech Republic were made according to (4) as well as (5) respectively. The 1915 South African specimens and the 1940s specimens from the Malaysian Hawaii New Caledonia and the Solomon Islands and the Islands of Mariana Guam and Palau.

H. illucens had most likely spread over its current range by the 1960 (6). The current range of *H. illucens* in North America appears to have expanded northward from the areas of northern South America and Central America where it was originally found in the past even though the fact that its exact original distribution is unknown and it seems not possible that it originated in the southeastern of America. By the late nineteenth century it had spread throughout the southern states of America (7). According to the United States National Museum the oldest specimen ever discovered dates back to 1881 as well as was found in Fernandina Florida. Riley and Howard in 1889 identified it (erroneously termed The Hermetia mucens) based on a specimen taken from Alabaman beehives in 1887. Additional records from 1899 (Texas) 1897

(Louisiana) 1911 in South Carolina Southern California 1923 and 1926 in Virginia Iowa (1931) and Ohio (1938) Northern California 1940 Maryland in 1943 and New York City in 1945 are known to exist (8). To the best of our knowledge the record for the northernmost location is from September 16, 1972 in Warner New Hampshire Merrimack County (Collection of the New Hampshire University) (9).

The species was not included in publications on the Diptera of Oregon (Cole and Lovett, 1921) or Kansas (Adams, 1903) (10). According to James's (1960) distribution chart the northernmost specimen in California can be found near the northernmost point of the Central Valley (7). Nevertheless, he also provides a map of North America and notes records from North Dakota Oregon and Washington state referring to them as "temporary local introductions." These records are not included in Woodley (2001) World catalogue. Since a large number of records from Oregon and Washington State are currently available we believe the species to be established in these states (11). From about 1972 until 1980 one of us (NEW) collected extensively in southeastern Washington but we never saw *H. illucens*. It now exists there suggesting that its distribution there is relatively recent. The majority of the Great Plains states the Rockies and western Canada do not appear to have any confirmed records (12).

2. Life Cycle of BSF:

A true fly (Diptera) is *Hermetia illucens*. It shows great promise as an affordable substitute for biological waste recycling. Adult BSFs only survive for about two weeks on water. Adult BSF flies lack stingers mouthparts and digestive organs therefore they do not bite and consume food as other flies do. The female BSF has a reddish brown abdomen whilst the male is 20–25 mm long with a bronze belly (13). A mature female BSF mates and releases her eggs just once in her lifetime. The BSF is a eurygamous bug that mates while in the air and needs wide spaces for its mating flight (14).

After two days mating takes place between the male and female BSF who emerged two days earlier. The females deposit their eggs in dry crevices close to the larval substrate where they hatch into neonate larvae in about four days. The larvae obtain their food from organic waste including composted plant matter food manure leftovers and municipal waste (15). In their final stage the larvae can reach maximum length of 27 mm maximum breadth of 6 mm and a maximum of 220 mg in weight. The final larval stage before pupation known as the prepupae uses this behavior to "self-harvest" by eliminating an arduous phase of their farming by emptying their digestive system and searching for a dry secure location to pupate after leaving the feeding source. The larvae have reached their maximum size at this stage consisting of 36–48% protein and 33% fat (16). In around 14 days they will develop into adults. The BSF life cycle which in the tropics takes an average of 40–43 days. However, depending on factors like food availability and other circumstances the cycle may stretch to 4 months during the larval and prepupal phases. When BSFL pupate and become adults they stop eating and consume as much organic garbage as they can (16). They use the fat that has been stored in their bodies to produce energy require for mating and continuous life cycle. Still the most important elements in guaranteeing a good BSF life cycle are environmental parameters including temperature light and humidity (16). This can be seen in figure 1.

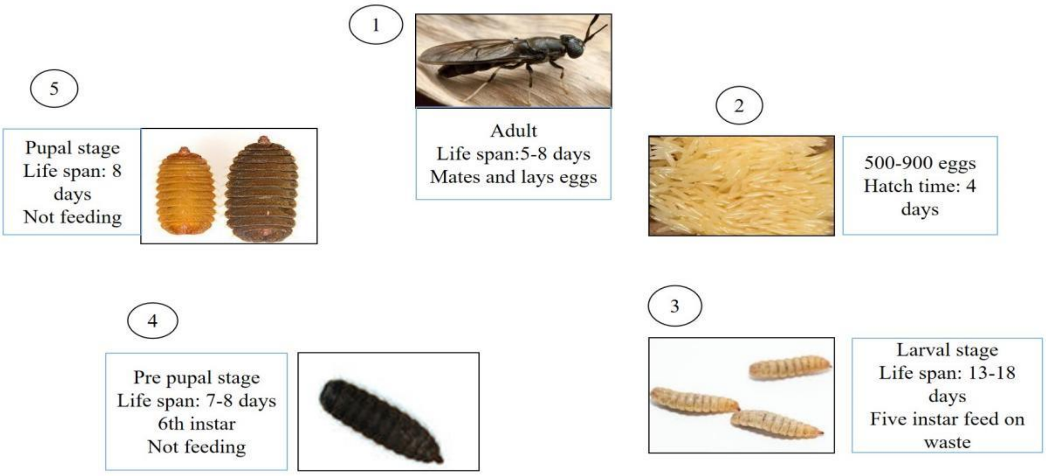

Figure 1: The Life cycle of BSF

3. Nutritional composition of BSF:

The results of increased living standards and an expanding human population in emerging nations will result in a rise in the need for protein sources produced from animals (17). Due to resource scarcity animal feedstock prices have increased in recent years. Animal feed now makes up 60–70% the cost of production in systems that produce animals putting human food and animal feed in challenger. For example, more substances such as seafood meal, fish oil and soybean meal and cereals are being used in animal feed as well as human food. Insects are a high quality and possibly lucrative feed source for production animals since they are proteinaceous and have high feed conversion and growth rates efficiencies (18). People have always consumed insects and this is still the case in many African countries. An estimated 2 billion people believe they enhance their diets. Food scarcity in numerous developing nations today and the difficulties of consumption more than Nine billion individuals by 2050 have drawn attention towards insects as a potentially important alternative source of protein. Due to anthropogenic factors such as urbanization growing incomes environmental issues nutritional issues and other issues the global food system is undergoing significant change. These factors have led to a dramatic shift in diets with a growing interest in eating insects expected in the upcoming decades (19). Energy protein and micronutrients are abundant in insects (such as Cu, Fe and Zn) as well as vital amino acids and fats. On the basis of dry matter crude protein components of most insects is greater than 30%. Generally speaking insects are rich in methionine, threonine and lysine three main necessary amino acids that are limited in low protein diets for pigs and poultry made up of wheat and legumes (20).

The fat content of BSF larvae varies from 7 to 39% dry matter (DM) which represents the largest variation in their body composition(16).Protein content varies between 37 and 63% DM in substrates (16). The type and amount of food consumed determines the larvae body composition even though larvae of BSF often have high protein and fat values. Regarding crude fat the same holds true (21). It is also possible for there to be notable variations in body composition when the larva is actually developing. For example, the amount of crude protein decreases with age the largest proportion was seen in larval stage that were 5 days old (61%) however it was lower for larvae that were 15 and 20 days old (44%) and 42% respectively. Fresh larvae have a dry matter concentration of 20–44% depending on their food and stage of development. This is because DM levels increase with subsequent instar (21).

The composition of fatty acid in BSF meal influenced by the meals the larvae were fed during their upbringing. BSF larvae and prepupae contain high levels of lauric acid, palmitic acid and oleic acid which have been found to contain between 58 and 72% saturated fat and between 19 and 40% mono- and polyunsaturated fat. The fatty acid composition of larvae and prepupae is depend upon the fatty acid composition of the diet (22). More fat in the food caused more fatty acid to be converted to lauric acid which suggests that there are many possibilities to change the fatty acid composition of BSF larvae. For example prepupae of BSF may incorporate some fatty acid such as α-linolenic acid or eicosapentaenoic acid when these content is found in their food (23). Calcium (Ca) was most prevalent mineral found in BSFL followed by phosphorous (P), potassium (K), sulphur (S), and magnesium (18). Other minerals in trace amounts included Na, Fe, Mn and Zn (24). In larvae glutamate glutamine aspartate asparagine and alanine were the most prevalent amino acids. Taurine and cysteine had the lowest amino acid levels in the larvae (25).

4. Waste management through BSF:

A rising level of living brought about by population increase can generate solid waste either directly or indirectly. The food business construction hazardous and agricultural industries all produce solid waste. With the world population expected to rise at an accelerated rate, more solid waste is expected to be generated. The present estimate of the world population is 7.6 billion but a United Nations study predicts that number projected to increase to 9.8 billion in 2050 and 8.6 billion in 2030 (26). For economic development the expansion of metropolitan areas and the rise of consumerist lifestyles have all contributed to notable developments in mass consumption mass production and disposal of waste in recent decades. These elements play a part in the ongoing production of significant amounts of garbage. Every day almost 1.3 million tonnes of solid trash are produced 3.4 billion tons in 2050 compared to two billion tonnes in 2016. Economically viable waste management depends on a number of factors including the kind of organic material the quantity of nutrients and the ratio of waste to biomass conversion (27). Many communities have worked harder during the last ten years to discover sustainable ways to manage their solid waste particularly in creating integrated solid waste management plans that involve building and running sanitary landfills. It is not surprising that scavenging or the valorization of recycling activities has become a revenue-generating activity carried out by the formal resource management authority or in collaboration with the informal sector in order to partially offset the rising expenses associated with waste management (28). Larvae of Black soldier fly are innovative waste management method that treat biowaste (27). This process reduces the dry mass of waste by converting garbage into larval biomass and raw materials are produced for the manufacture of fertilizer and soil conditioner lubricants bio diesel medicines and animal feeds (29). The capacity of BSFL to expand by consuming a lot of organic wastes up till the prepupae stage is what makes them special. In a shorter amount of time BSFL composting works better than conventional composting at reducing organic waste by 50%. As a result, BSF is an environmentally friendly substitute for handling organic waste. Using BSF to treat organic waste is less expensive and produces less pollution. Large-scale facilities handle up to 200 tonnes of trash per day and create protein using BSFL(30). Particular cause for concern is the erratic dependability and effectiveness of BSFL organic waste treatment. In BSF treatment a variety of organic wastes are utilized as a substrate such as human feces, dairy manure, chicken waste and kitchen waste. The macronutrients, protein, carbohydrates, fibre, and fats found in organic wastes have a significant influence on the process efficiency (16).

Protein is a necessary ingredient of substrates used for larval feeding because it significantly improves the development of larvae (30). If the carbohydrate content is high larvae feeding on low-protein substrates develop more slowly are smaller and contain more lipids. The performance of the BSFL is impacted by the varying nutritional concentrations of the organic wastes. For instance, municipal organic solid waste and animal dung have higher protein levels than fruits and vegetables which have higher carbohydrate contents. Similarly the highest lipid amounts are found in municipal organic solid waste (16). Therefore, the process performance and quality of BSFL biomass can be improved by balancing and improving the nutritional content of the BSFL feeding substrates by combining multiple nutrient rich substrates during the pretreatment stage.

Feed type quantity and quality as well as a number of environmental variables affect how well BSFL therapy works. The larvae and frass that must be removed to produce useful items like animal fodder and fertilizer are by products of the waste treatment procedure for BSFL. In the life cycle of a BSF feeding occurs only during the larval stage. BSFL stores up enough proteins and lipids during this time. After going through pupation the larvae become adult flies and leave behind a residue known as frass (31). Under the BSF system until they reach the pre pupae stage for growing the A wide range of organic substrates including garbage and decomposable materials can be consumed by larvae. The pupae can be easily separated from the frass with the help of daily food additions, a drainage system to remove excess leachate and a ramp for the pre pupae to climb out of the larvae (32).

5. Frass from BSF used as organic fertilizer:

Another significant byproduct of the BSFL treatment in addition to prepupae/larvae is a valuable residue called frass which is a combination of uneaten substrates and shed exoskeletons (16). Bioconversion of waste material by BSFL yields frass which accounts for roughly 30 to 50% of the feeding substratess initial weight. The frass is collected after eighty to ninety percent of the larvae have developed into prepupae (33). Utilizing frass as organic fertilizer is a relatively recent concept because it shares traits with immature compost. Utilizing BSFL organic fertilizer sustainably can help lessen the over-reliance on expensive mineral fertilizer which are bad for the environment and the land. Grass has large content of majornutrients (nitrogen (N), phosphorous (P), potassium (K), tracenutrients and organic mattter that makes it suitable for utilization in agriculture (34). BSFL composting happens so quickly the frass needs to be post processed first because it is not mature. Maturation is an essential procedure that lowers the frass microorganism activity and the soil it is applied to compete for nitrogen and oxygen (O). Anaerobic digestion and vermi composting are two methods for achieving frass maturation (35). Methane generation from insect wastes such BSFL frass is feasible and results in a fertilizer with higher quality since the bio methane potential of the material is comparable to the material utilized in biogas facilities. The simplest approach is composting which entails placing the trash in the soil after three weeks of it being abandoned beneath a roof on a concrete surface.

Because biogas plants can be expensive to run. For the BSFL frass to stabilize post treatment is required (36). Plant growth is stimulated by applying frassr. Plant development is not much different when utilizing ordinary compost versus frass. In addition to fortifying plant resistance to illnesses and infections BSFL frass chitin may also raise the levels of nitrogen and phosphorus Organic matter in the soil (37). It is important to remember though that if fresh BSFL frass is sprayed incorrectly it might inhibit plant growth(38). For instance, the limited porosity of new frass may have resulted in anaerobic or low-oxygen circumstances due to the poor growth of the maize plants. In order to breathe and grow healthily plants need well aerated soil (39). Frass for fertilization purposes use to promote the growth of food crops (40). Consequently further investigation in order to improve BSFL frass quality as an organic fertilizer post treatment is necessary and position it as a superior substitute for chemical fertilizers in terms of plant development(40). This is shown in figure 2.

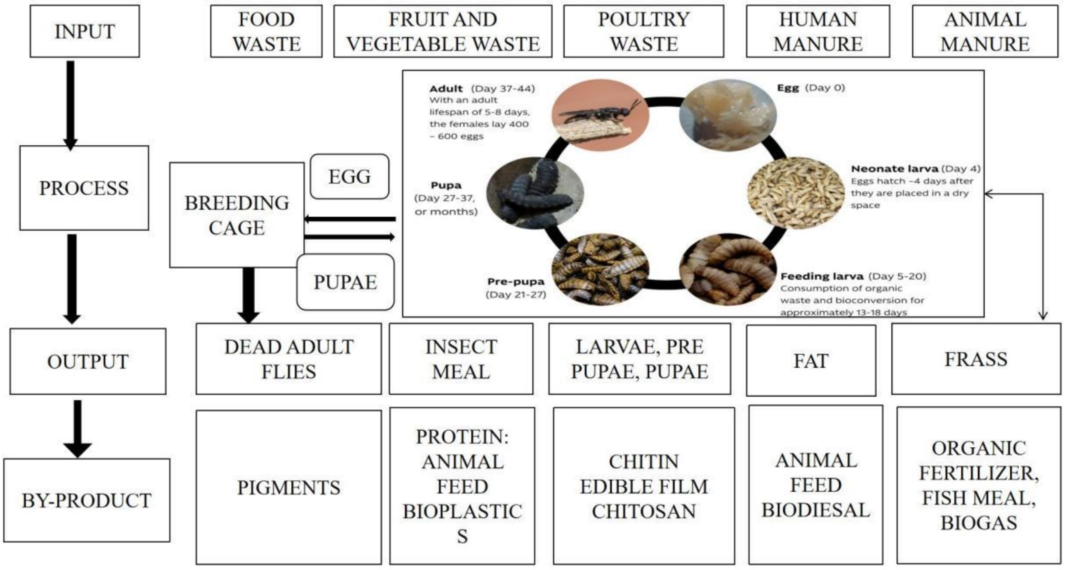

Figure 2: Flow sheet diagram of BSLF waste management process

5. Livestock feed made from Black Soldier Fly:

The larval instars of this insect *Hermetia illucens* are dried and ground into a meal known as black soldier fly meal. It has been demonstrated that black soldier fly insect meal enhances both animal growth and food digestion. Vitamins and animal protein bound in this made of insects. It can be used to replace the expensive ingredients that are added to fish soy and grain meals for livestock feeding (34). The ideal sample species for preparing insect meals are the larval instars of the insect *H.illucens*. The black soldier fly larval instars are deserving of commendable efficiency in converting waste materials into protein-rich products. The difficulty in using the larval instars of the black soldier fly to produce food products high in protein resides in human capacity to harvest in a sustainable manners in order to satisfy world demand (34).

A billion people in South Asia and Sub-Saharan Africa rely only on the production of livestock for their food and means of subsistence according to reports published by the FAO in 2015 (41). The majority of agricultural land is used for raising cattle for grazing (or cultivating feed crops). Due to enteric fermentation and the creation of manure livestock animals are the source of the greatest emissions of greenhouse gases. The greenhouse gases released by livestock animals are a major cause of climate change. Livestock farming has a detrimental impact on the environment specifically the land water and biodiversity resources. Finding substitutes for the qualitative techniques of production through agricultural practices is therefore of utmost importance (42, 43).

7. BSLF as Fish feed:

Carnivorous fish and other animals are fed fish meal and fish oil are already considered to be animal grade substitutes for BSFL meal and oil due to large amount of protein and fat even when given waste streams made of plants (44). The significance of fish oil and meal in aquaculture is widely recognized. Different elements including depleted fisheries and rivalry with the need for fish to be consumed by humans have caused supplies oil and meal of fishes to decline and costs to rise driving fisheries to seek alternatives such as vegetable oils (41). Fish prefer BSFL over vegetable oils because they can accumulate body fat if fed a high enough fat meal. Incorporating fish offal into the larval diet results in the production of prepupae with improved omega-3 fatty acid levels. When compared to fish meal these riches pre pupae demonstrate no discernible changes in fish growth and visual development making them ideal fish meals for *Oncorhynchus mykiss*. Fish fed enriched BSFL diets or fish meal BSFL diets did not differ from one another according to a sensory analysis of trout fillets. Although the amount of healthy polyunsaturated fats in rainbow trout decreased defatted BSFL supplementation in the diet was found to be safe and effective with no negative impacts on the physiology of the fish or the physical quality of the fillet.

The upper limit for unaffected fish development in another investigation on rainbow trout was shown to be 15% BSFL in the diet. When BSFL oil content in the diet increased, lipid deposition in juvenile Jian carp decreased, but BSFL oil and soybean oil did not differ in terms of growth performance. Because the turbo Psetta maxima was raised on local greenhouse wastes use of BSFL meals was nonetheless advised as a practicala partial substitute for fish meal in spite of the meals relatively low palatability and nutritional content. Due to their reduced cost BSFL suggested as a nutritional substitute for fish meal containing just 25% of fish meal as demonstrated by experiments with the *Clarias gariepinusn* (45). These results showed no effect on growth rate or nutrient utilization indices. Many writers have come to the conclusion that because efficiently producing protein rich edible biomass from organic wastes that may be low in protein, BSFL can make a substantial contribution to sustainable aquaculture by serving as a partial or complete meal replacement for aquatic invertebrates like prawns (41).

8. BSLF as Poultry feed:

In large part because the species naturally occurs in colonies and decomposes chicken excrement because poultry farms frequently maintain populations of BSFL for the goal of waste treatment and pollution reduction Additionally BSFL has been utilized in chicken feed to partially replace feeds based on soy or maize.Supplementing with BSFL had no effect on the sensory characteristics flavour perceptions, oxidative status or composition of cholesterol in breast meat (46).But there was an improvement in the amino acid composition of meat with greater amounts of aspartic acid glutamic acid alanine serine tyrosine and threonine (47). On the other hand it raised levels of saturated and monounsaturated fatty acids which are less favourable. when broiler chickens (*Gallus gallus domesticus*) were fed BSFL supplements with the exception that the adverse effects on the profiles of fatty acids were lessened when defatted BSFL was used. Participation in the BSFL guaranteed successful and fulfilling performances favorable body composition and overall eating habits and the possibility of using it as a source of protein for chicken feed (48). There was little to no influence on the eggs themselves and no impact on the laying hens performance or health when 50% of their diet was replaced with soybean cake or supplemented with BSFL. Poultry find BSFL to be extremely tasty as well it has been shown that laying hens will actively rather than continuing to consume the ad libidum wheat soy meals look for BSFL from feeders (49).Because they may be raised on the excrement of the same birds that eat them BSFL offers an additional protein source and a means of recycling and valorizing waste materials at the same time making them a potential partial replacement for poultry feed. Pig manure mass and nutritional value have also been observed to decrease due to black soldier flies just like they do with chicken dung (50). Better farm cleanliness fewer the benefits of this include decreased nutrient contamination in overflow and pest fly populations. Even if there would not be enough flies to feed the pig. The residual manure residue could be utilized for farming allowing plants to thrive in other inappropriate soils or even sand. Because pure dairy manure has a high crude fibre content that the flies are unable to properly process it is frequently blended with other ingredients to optimize larval production and overall reduction of waste for BSFL rearing. In order to further valorize wastes from the manufacture of human food BSFL can also be raised on offal and blood from slaughterhouses (51).

Because of this it is widely recognized that BSFL can feed a wide range of vertebrates and may serve as a substrate for different vertebrate wastes. This has important implications for lower input sustainable agriculture in developing nations and has no bearing on the human taste of meat produced using BSFL. Possible advantages of BSFL and other insect feeds are greatest in developing countries but Advanced economic such as the United States should anticipate playing a bigger role in the future. Because food conglomerates promise to cut waste in order to win over consumers and regulators who are becoming more environmentally conscious. Additionally producers will be forced to find alternatives due to the unstable costs of fish meal and other feeds (52).

9. BSFL as pig feed:

Because of its excellent palatability and high calcium and amino acid content Pig diets benefit from the addition of BSF larval meal (49).But because lack of cystine and methionine balanced diets must include those amino acids (43). Furthermore it would be preferable to combine BSF larvae with other proteinaceous substances due to their elevated levels of ash and crude fat (53). When comparing pigs fed soybean meal to BSF larval meal, the apparent digestibilities of dry matter and nitrogen were generally higher (85.3 and 77.2 vs. 77.5 and 76%, respectively). Furthermore weaned pigs did not perform well on BSF larval diet suggesting that rendering and cuticle removal are two further refinements that may be needed to improve early weaned pig performance (54). Additionally weaned pigs did not perform well on the BSF larval diet indicating that rendering and cuticle removal are two more improvements that might be required to enhance the performance of early weaned pigs (49).

10. BSF used as animal feed for different species:

Animals such as mountain *Leptodactylus fallax* and alligators (*Alligator mississippiensis*) have been fed whole BSF larvae and pupae. When BSF larvae were given to juvenile alligators in place of commercial feeds the consumption and growth of the alligators were reduced. The mountain chicken frogs poor nutritional digestibility was caused by feeding them BSF larvae (55). It appears that animals that, like these species, consume their food whole could benefit less from an unprocessed version of BSF. For instance, the digestibility of calcium for the whole BSF larvae in frogs was just 44% whereas that of "mashed" BSF larvae was 88%. Effective use of BSF larvae has been used as a source of minerals in a variety of lizard and amphibian species captive feeding and breeding programme (56). When fed to commercial giant river shrimp (*Macrobrachium rosenbergii*) the leftovers from BSF raised on dry distiller grains were found to perform similarly to standard prawn feed and yield higher financial returns (57).

11.Production of Biodiesel from BSLF:

For use in compression ignition engines biodiesel is the monoalkyl esters of long chain fatty acids made from renewable feedstock such as vegetable or animal fats (49). .With no modifications biodiesel may be utilized safely in existing diesel engines and provide the same power output as regular diesel (32). Trans esterification the most widely used technique for creating biodiesel involves combining alcohol natural oil and a catalyst. Because of its excellent energy efficiency it is advantageous in the cutthroat energy market (58).

Transesterification was done in two steps to create biodiesel. A procedure known as acid catalyzed esterification was used to reduce the amount of Free fatty acid in the crude oil. The esterified oil is transformed into biodiesel using an alkaline catalyzed transesterification process. For the acid catalyzed esterification process BSF larval oil was placed in a conical flask and methanol and sulfuric acid were subsequently added (59). The final mixture was then centrifuged for 10 minutes at 400 rpm after being agitated for a specific amount of reaction time. Subsequently the top layer was moved to a conical flask and allowed to dry for ten minutes at 105°C in an oven. In order to do the alkaline-catalyzed transesterification esterified oil were put into a conical flask heated to a specific temperature then the combination of methanol and sodium hydroxide was added and agitated for a predetermined amount of reaction times. Biodiesel was then extracted from the mixture after it had been separated for ten minutes at 400 rpm in a centrifuge. The reaction mixture forms a two phase interface as a result of the vaporization of methanol (60).

Because of its biological characteristics *H. illucens* has been widely used to treat common organic wastesuch as home agricultural and poultry manure without causing pollution. Through this process organic waste is transformed into useful forms that are then fed to insect biomass (61). Oil extracted from BSF prepupae has a good fatty acid composition which could result in a biodiesel of superior grade. In the age of biofuels the manufacture of biodiesel from insects that rely on organic waste has enormous potential and is gaining popularity in continents in development such as Asia Africa and the Middle East. It will lessen the need for fossil fuels mitigate their detrimental effects on the environment and lower the price of biodiesel (62).

Conclusion:

In conclusion, the BSFL is very important economically. When used as a food source BSFL can offer affordable nutrient dense and sustainable sources of protein fat and carbohydrates and a substitute for chitin. Even though there is a lot of encouraging data on BSFL as a potential replacement for protein it has mostly been viewed as animal feed up until now which may discourage people from using them as food. Emerging biowaste treatment technology known as BSFL biowaste processing can provide high value marketable products that support sustainable and profitable development resource recovery based approaches to waste management. One technological challenge is getting BSFL to operate efficiently, treatment and secure production of larvae and residues using a variety of biowaste streams with varying properties. In order to facilitate the development and utilization of BSFL in the food industry it is imperative to develop and optimize BSFL farming practices that yield a consistent safe and affordable supply.

Conflict of interest

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Authors contribution

All authors contributed equally in the manuscript.

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